

Redshift and spatial distribution of the intermediate gamma-ray bursts

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Abstract.

One of the most important task of the Gamma-Ray Burst field is the classification of the bursts. Many researches have proven the existence of the third kind (intermediate duration) of GRBs in the BATSE data. Recent works have analyzed BeppoSax and Swift observations and can also identify three types of GRBs in the data sets. However, the class memberships are probabilistic we have enough observed redshifts to calculate the redshift and spatial distribution of the intermediate GRBs. They are significantly farther than the short bursts and seems to be closer than the long ones.

Keywords: gamma rays: bursts

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INTRODUCTION

In the Third BATSE Catalog — using uni- and multi-variate analyses — Horváth [1] and Mukherjee et al. [2] found a third type of GRBs. Later several papers [3, 4, 5, 6, 7, 8, 9, 10] confirmed the existence of this third ("intermediate" in duration) group in the same database. Here we classify the 237 GRBs from the Swift first BAT catalog [11]. Using this result we calculated the redshift distributions for the classes.

CLASSIFICATION OF SWIFT GRBS

The probability distribution of the logarithm of durations (x) can be well fitted by Gaussian distributions, if we restrict ourselves to the short and long GRBs [1]. We assume the same also for the y coordinate. With this assumption we obtain, for a certain l -th class of GRBs,

$$p(x, y|l) = \frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-r^2}} \times \exp \left[-\frac{1}{2(1-r^2)} \left(\frac{(x-a_x)^2}{\sigma_x^2} + \frac{(y-a_y)^2}{\sigma_y^2} - \frac{2r(x-a_x)(y-a_y)}{\sigma_x\sigma_y} \right) \right] \quad (1)$$

where a_x, a_y are the means, σ_x, σ_y are the dispersions, and r is the correlation coefficient. Hence, a certain class is defined by five independent parameters, $a_x, a_y, \sigma_x, \sigma_y$, and r , which are different for different l . If we have k classes, then we have $(6k - 1)$ independent parameters (constants), because any class is given by the five parameters of Eq.(1) and the weight p_l of the class. One weight is not independent, because $\sum_{l=1}^k p_l = 1$. The sum of k functions defined by Eq.(1) gives the theoretical function of the fit.

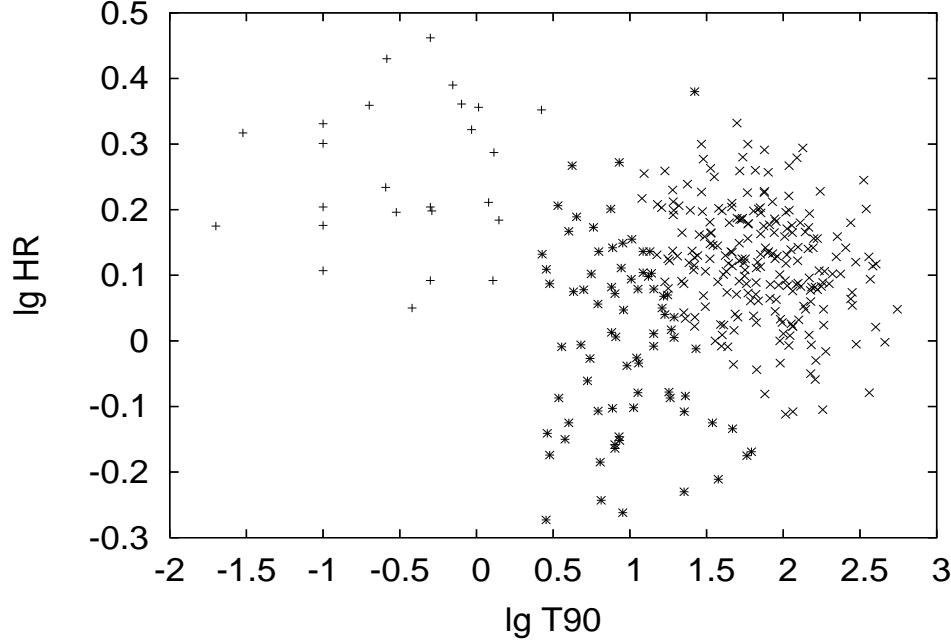


FIGURE 1. The classification result in the duration (x) - hardness (y) plane. Different symbols mark different classes.

The result of the three-Gaussian fit is shown in Figure 1. The best parameters were published in Horváth et al. 2010 [12]. Moving from $k = 2$ to $k = 3$ the number of parameters m increases by 6 (from 11 to 17) and L_{max} grows from 506.6 to 531.4. The increase in L_{max} by a value of 25 corresponds to a value of 50 for a χ^2_6 distribution. The probability χ^2_6 for 50 is very low (10^{-8}), therefore we conclude that the inclusion of a third class is well justified. Moving from $k = 3$ to $k = 4$, however, the improvement in L_{max} is 3.4 (from 531.4 to 534.8), which can happen by chance with a probability of 33.9%. Hence, the inclusion of the fourth class is not justified.

REDSHIFT DISTRIBUTIONS

The cumulative redshift distribution of the three populations is shown in Figure 2. Redshifts were taken from [13]. Only a subset of the classified bursts had redshift information and we considered bursts where the probability of belonging to a given population is higher than 97%. This means 6 short, 9 intermediate, and 50 long GRBs. The long and short population redshift distributions are significantly different (99.4%

significance). The intermediate GRBs redshift distribution is clearly between the short and long redshift distributions, which could mean that they are further than the short bursts and closer than the long ones. However, probably owing to the small number of data points the difference is not significant. We have tried several statistical tests. None of them showed high significance; the best one was 92%.

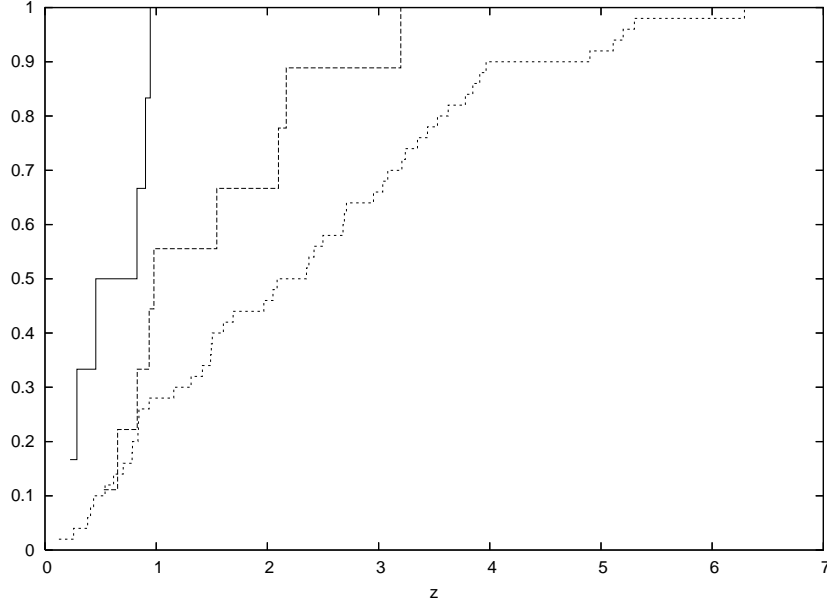


FIGURE 2. Cumulative redshift distribution of the three classes. The continuous line is the short, the dashed line is the intermediate, and the dotted line is the long population.

THE $E_{\text{peak}} - E_{\text{iso}}$ (AMATI) RELATION

Once we classify the bursts, it is also possible to investigate their properties in the context of the $E_{\text{peak}} - E_{\text{iso}}$ or Amati-relation [13] in the case of bursts with measured redshift. We have 18 redshifts from the long population and 6 from the intermediate. Both groups seem to follow the same relationship. As the Amati-relation is not valid for the short population, the intermediate bursts are more closely related to the long population than to the short class. Intermediate bursts do not populate the most energetic regime of the $E_{\text{peak}} - E_{\text{iso}}$ plane unlike the long bursts (see Figure 3). They tend to have lower isotropic energies compared to the long population. The small number of data points makes hard to give firm assertions at this time. Also, there is no significant clustering of intermediate bursts on this plane.

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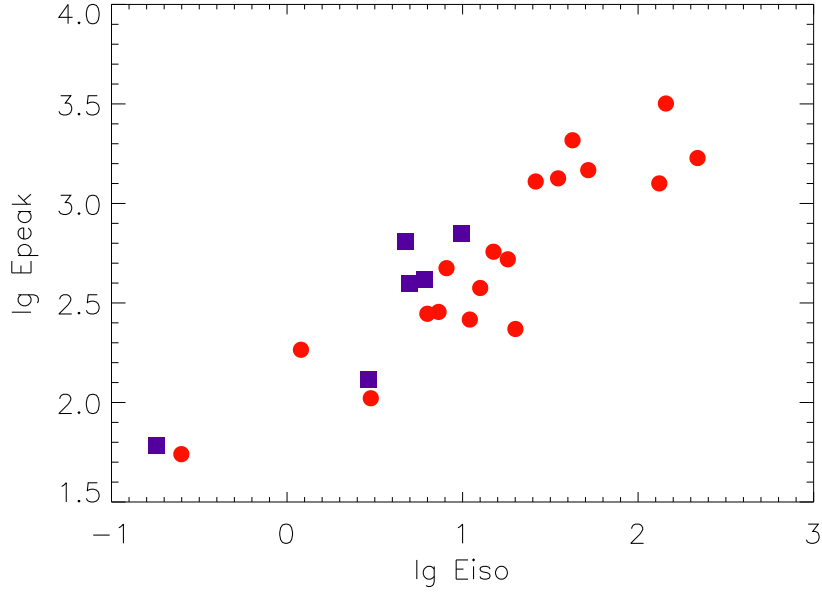


FIGURE 3. $E_{\text{peak}} - E_{\text{iso}}$ relation of the classified bursts. Circles represent long GRBs, and intermediate bursts are plotted in square. The y-axis is the 10-base logarithm of E_{peak} in keV, and the x-axis is the 10-base logarithm of E_{iso} in units of 10^{52} erg/s.

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